

**SOME EXAMPLES OF THE DEGRADATION
OF PROPERTIES OF MATERIALS IN SPACE**

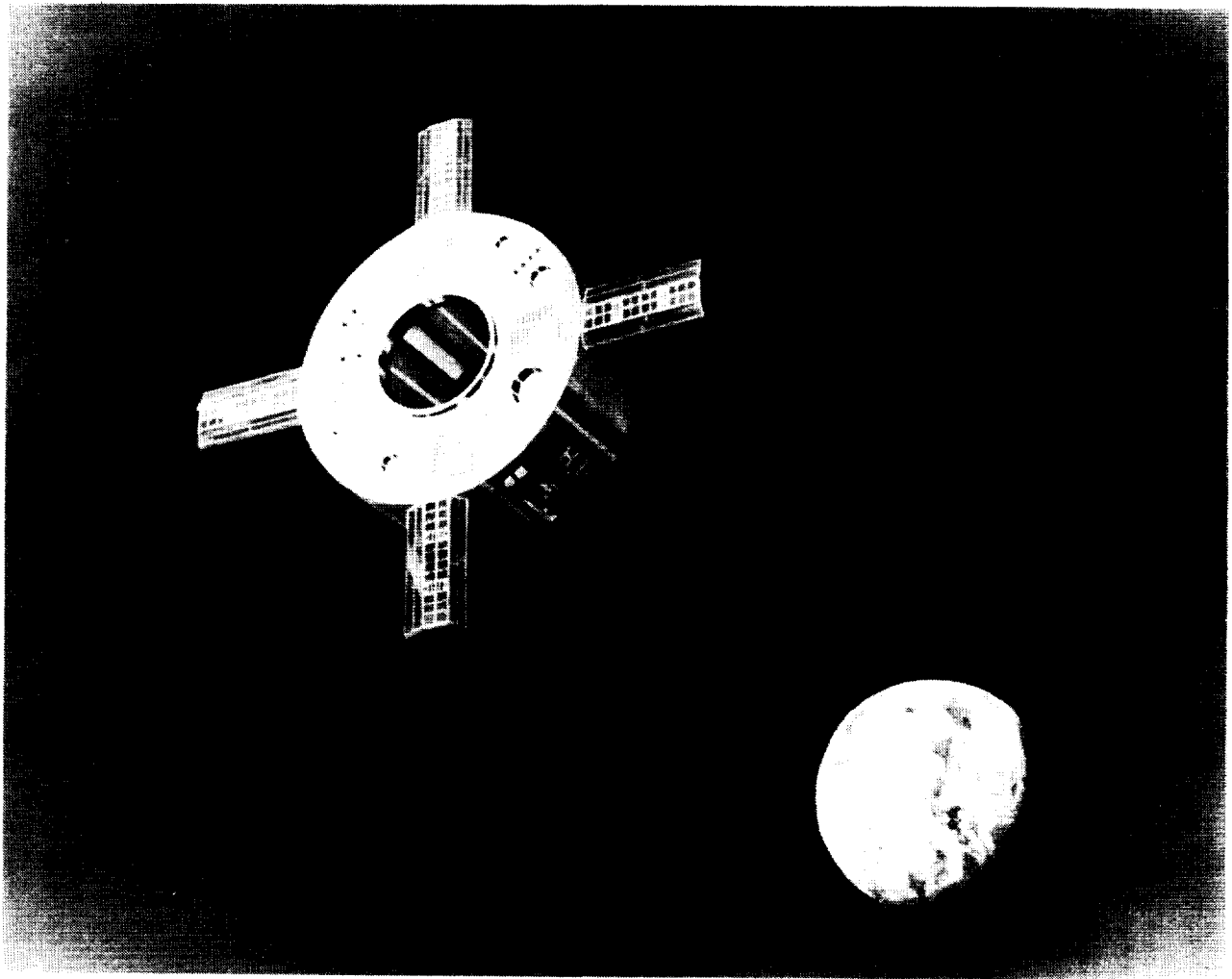
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SOLRAD 11 SPACECRAFT

An artist's conception of one of the two Naval Research Laboratory (NRL) SOLRAD 11 satellites that were launched on 14 March 1976 from Cape Canaveral is shown in figure 1. These spacecraft, the 65th and 66th launched by NRL, were in a 63,000 nautical mile circular orbit, spin stabilized and sun pointing. The prime power was provided by four deployed solar panels and four body mounted panels insulated from the body with a multi-layer insulation blanket.



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Figure 1

SOLAR CELL AND SILVER TEFLON PANEL LAYOUT

One of the four body mounted panels is depicted in figure 2. Overall dimensions of the panel were 25.4 cm (10.0 in) by 33.0 cm (130 in). On the panel was mounted an 80 cell series circuit of 2 cm by 2 cm solar cells and the non-cell area was covered with .13 mm (.005 in) thick silver teflon for thermal control. The solar cells, terminals, etc., accounted for 42.1%, and silver teflon 57.9% of the panel area. As I recall, the design operating temperature was about 50°C.

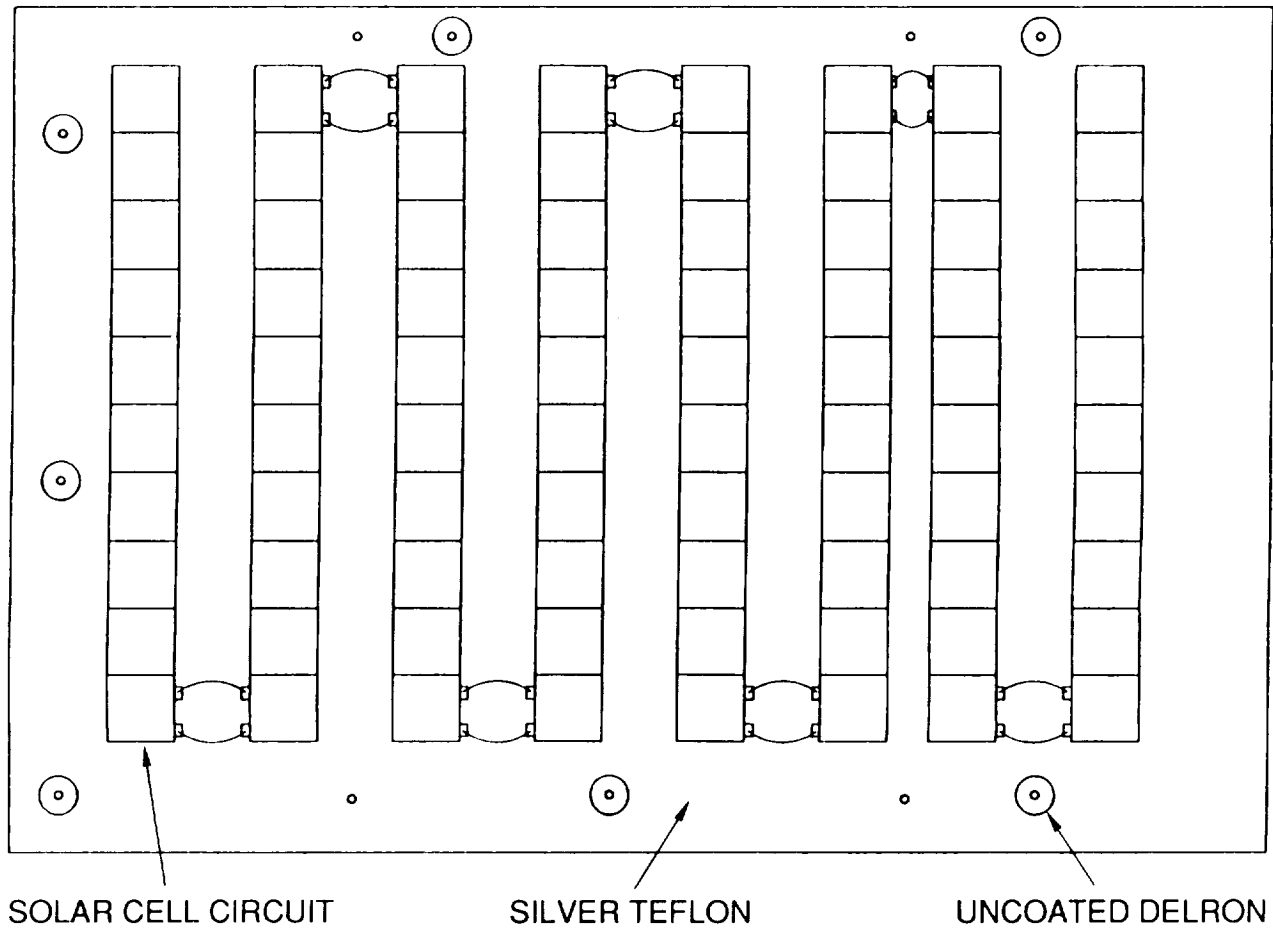


Figure 2

SOLRAD 11B SOLAR PANEL TEMPERATURE

Figure 3 is a smoothed plot of the insulated solar panel temperature versus time in orbit. The "waves" are caused by the annual variation in solar intensity due to the Earth's slightly elliptical path around the sun. Solar panel electrical output was reduced due to a non-optimum operating voltage resulting from the elevated temperature. Mission impact was minimal since higher voltage was only needed to recharge batteries after eclipses, which occurred about 30 times each year. Understanding the increase in temperature was a greater concern.

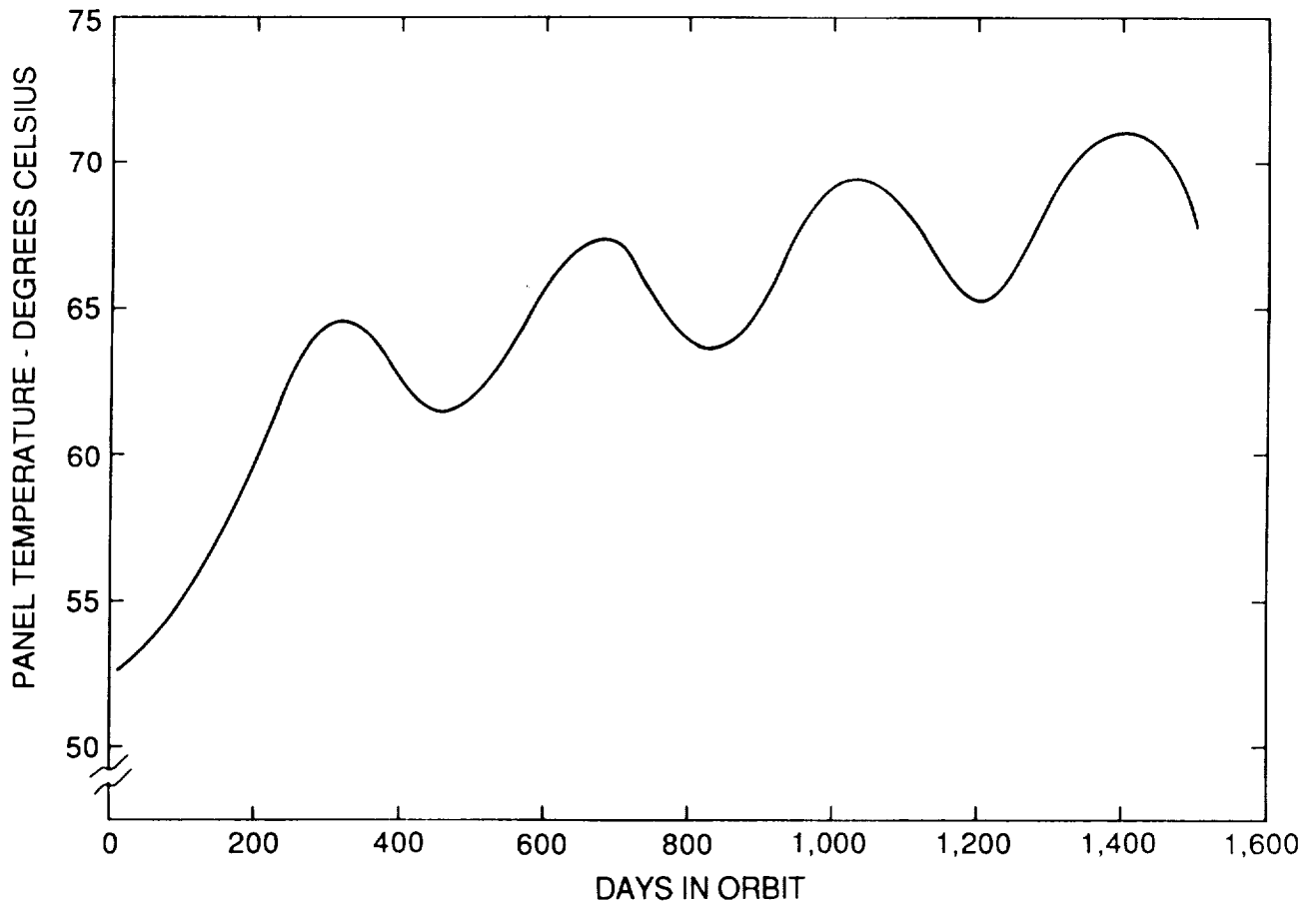


Figure 3

ESTIMATED CHANGE IN SILVER-TEFLON SOLAR ABSORBTANCE

It is reasonable to assume that the temperature increase is driven by an increase in the solar absorbtance of the silver teflon. I am not aware of changes occurring in material emittance. Inorganic silicon solar cell absorbtance, already high, should not increase; and the reduction in solar cell efficiency is negligible. A least squares fit of the absorbtance value, derived from panel temperature, is shown in figure 4 over a period of 1500 days in orbit.

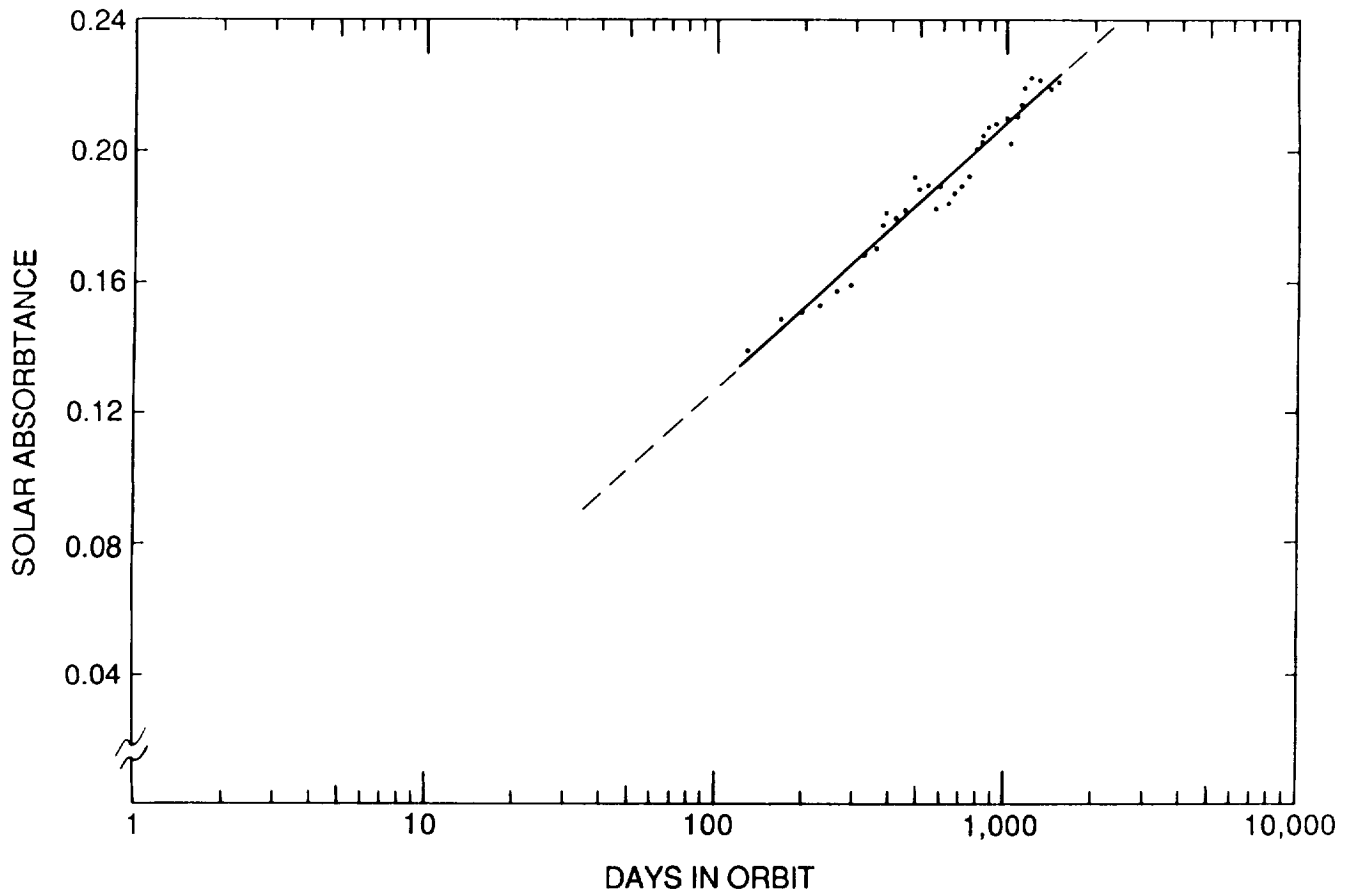


Figure 4

NAVIGATION TECHNOLOGY SATELLITE-2 (NTS-2)

While data was accumulating from SOLRAD 11, NRL was preparing NTS-2 for launch. Thermal design and engineering was contracted to the A.D. Little, Inc. Both Optical Solar Reflections (OSR) and silver teflon were incorporated for thermal control. Additionally, NASA Goddard Space Flight Center had a thermal control coatings experiment aboard with eight sample materials including OSR's and silver teflon. Internal deck temperatures exceeded the worst case temperature based on predicted degraded optical properties and maximum solar constant after less than two months on orbit.

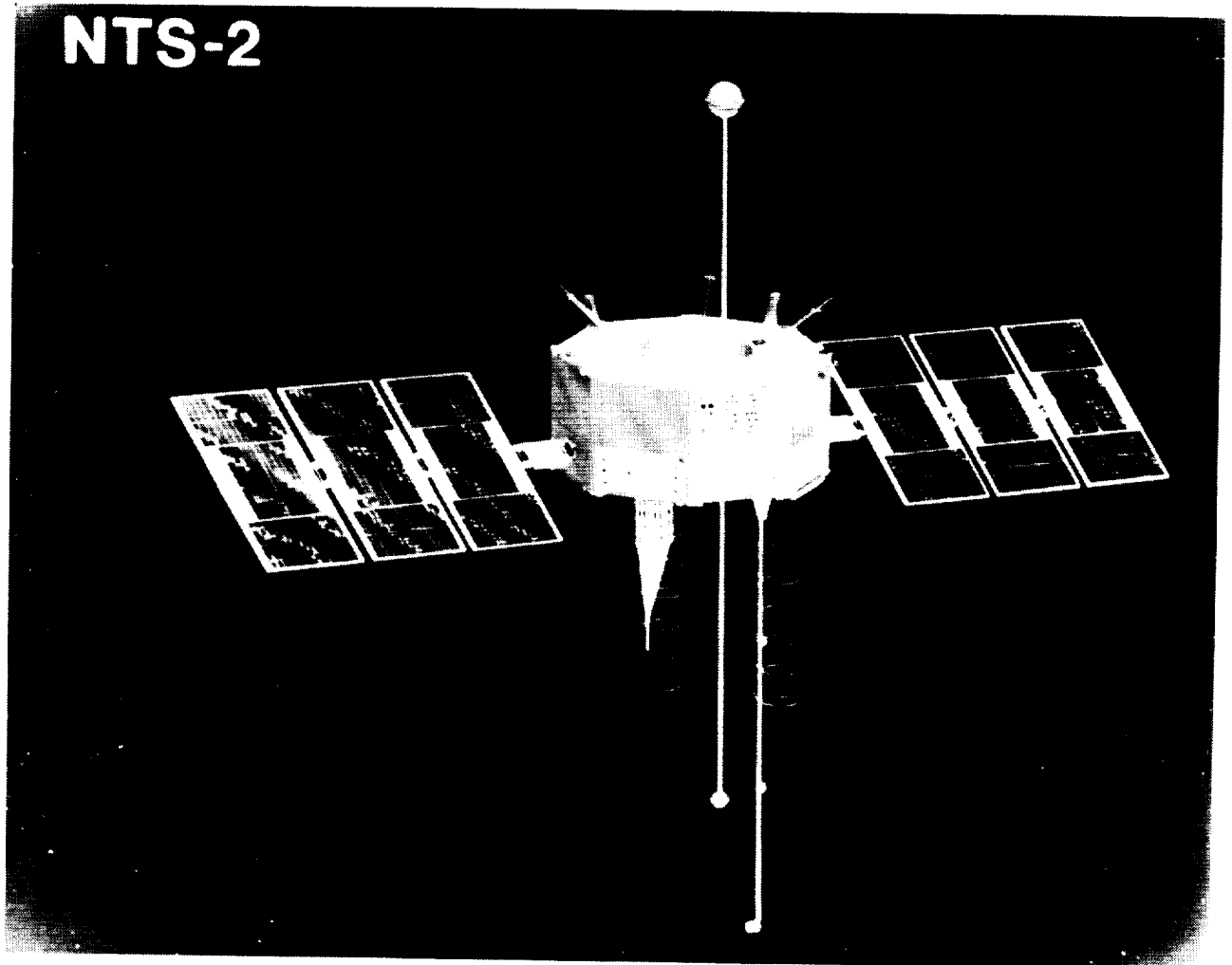


Figure 5

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MEASURED DEGRADATION IN SOLAR ABSORBANCE
OF OSR AND SILVER TEFLON ON NTS-2

Figure 6 combines data from the NASA-GSFC experiment and thermal analysis of NTS-2 spacecraft equipment, deck, and radiator temperatures. D.W. Almgren of A.D. Little, Inc., concluded that the nonlinear nature of the data suggested contamination and, in an internal technical report, described four conceivable contamination mechanisms. Three mechanisms were based principally on "desorptive transfer". The solar panels were folded around the vehicle for launch and the first 14 days on orbit and provided the intermediate transfer surface. (The figure is from D.W. Almgren's report).

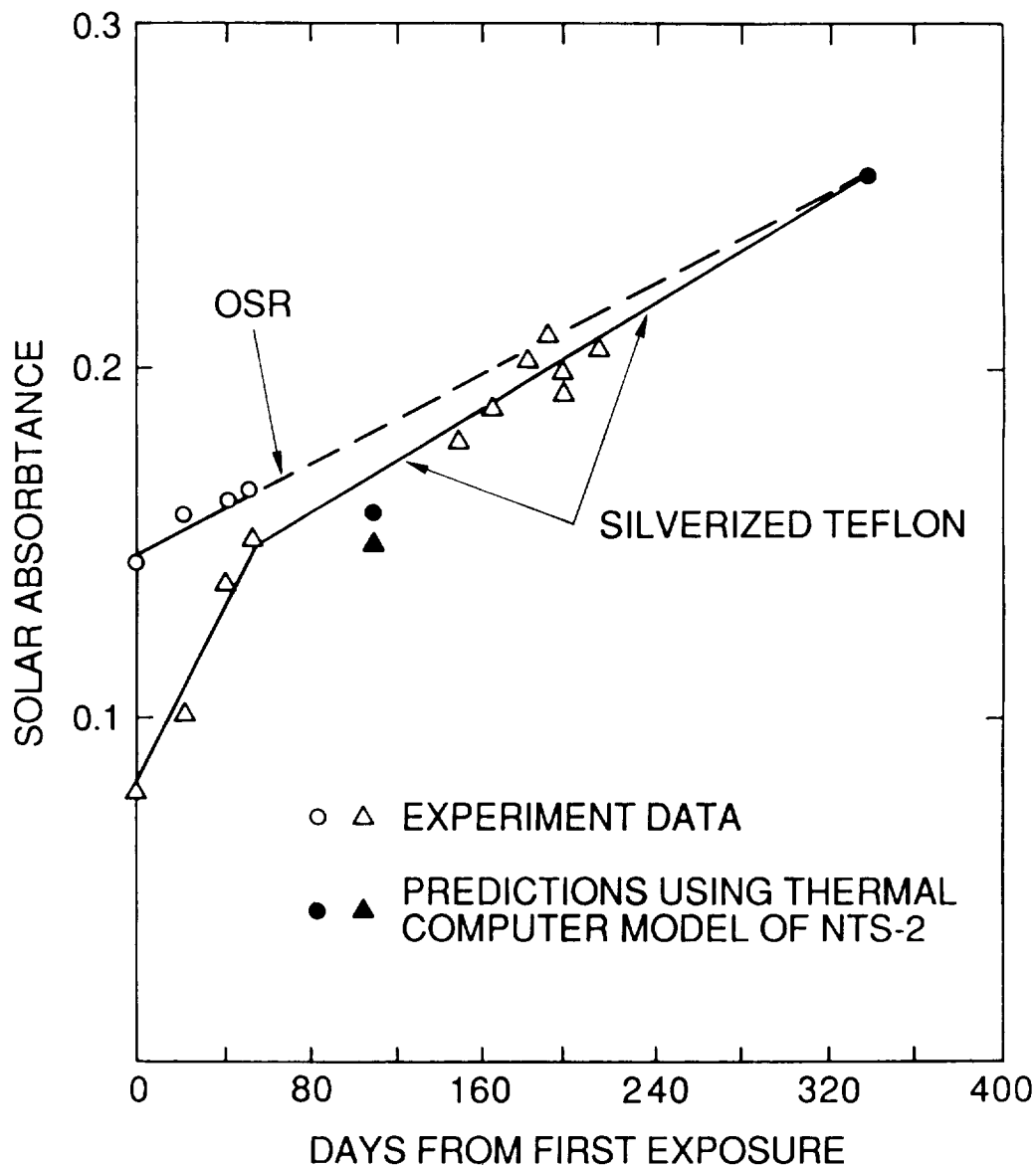


Figure 6

TEMPERATURE OF A SILVER TEFLON COVERED,
EARTH FACING, RADIATOR FOR SEVEN YEARS IN LOW EARTH ORBIT

Thermal analysis of the change in temperature of an Earth facing radiator over a seven year period, as shown in figure 7, resulted in an estimated change in solar absorbtance of 0.27. Assuming an initial 0.08 absorbtance, the final value totaled 0.35. A similar vehicle with only 4.5 years in orbit has shown an increase in absorbtance of only 0.13 based on thermal analysis. Interestingly, the thermal analyst finding these results displeasing, performed a "sensitivity" analysis, adjusting heat flow and temperature change interpretation to reduce the change in absorbtance by more than a factor of two.

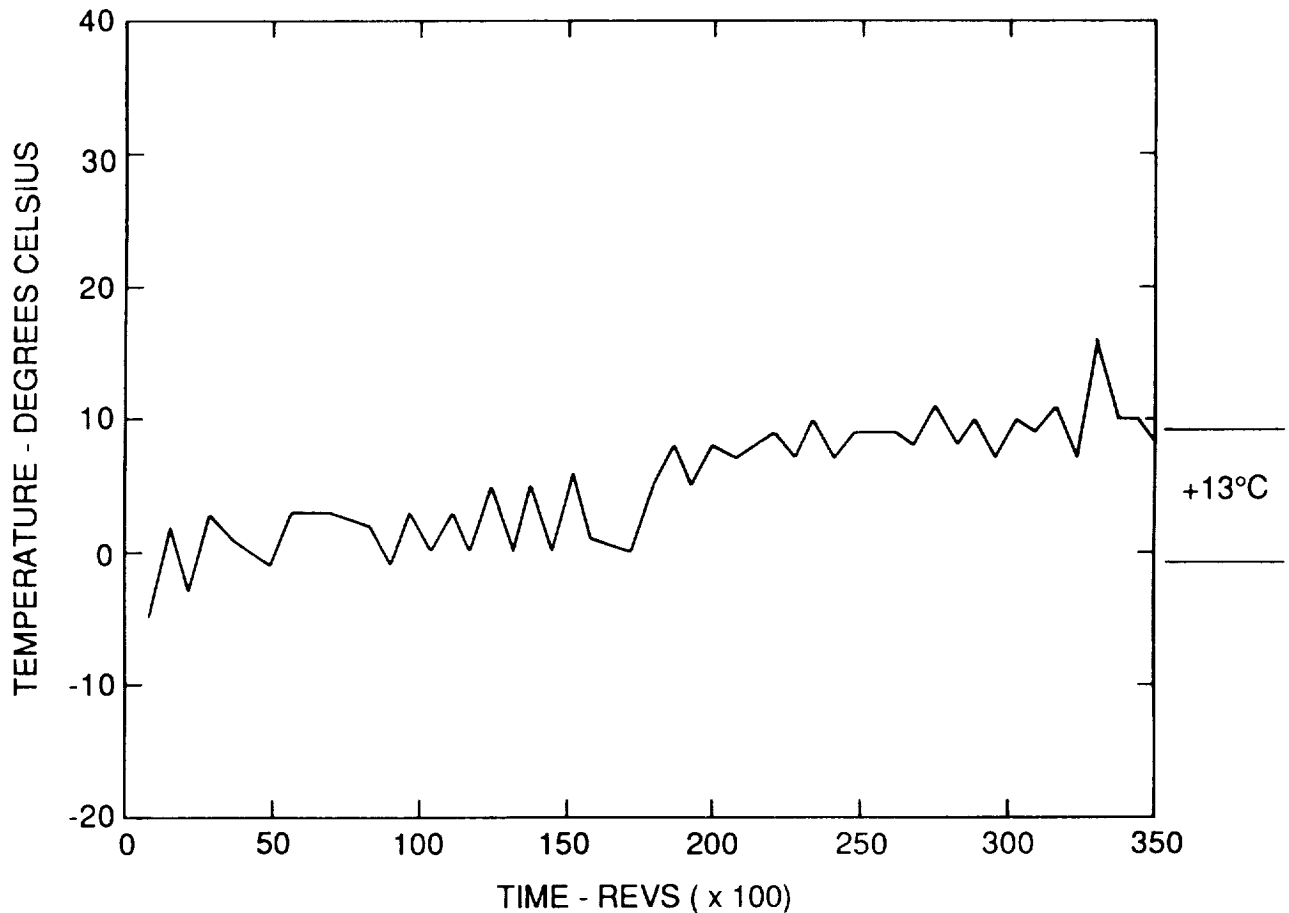


Figure 7

EXPERIMENTS 3 AND 4, SOLAR CELL SHORT CIRCUIT CURRENT DEGRADATION

NTS-2 also carried solar cell experiments. Shown in figure 8 is the difference in percent of initial on orbit short circuit current of identical solar cell and cover slide circuits. The only difference was that experiment 3 coverslide had anti-reflective coating and ultra-violet filters and was bonded with space quality organic adhesive DC 93-500, while experiment 4 cover slide had no coatings or filter and was bonded with fluorinated ethylene propylene (FEP) teflon. The data is from NRL Memorandum Report 4580 (ref 1).

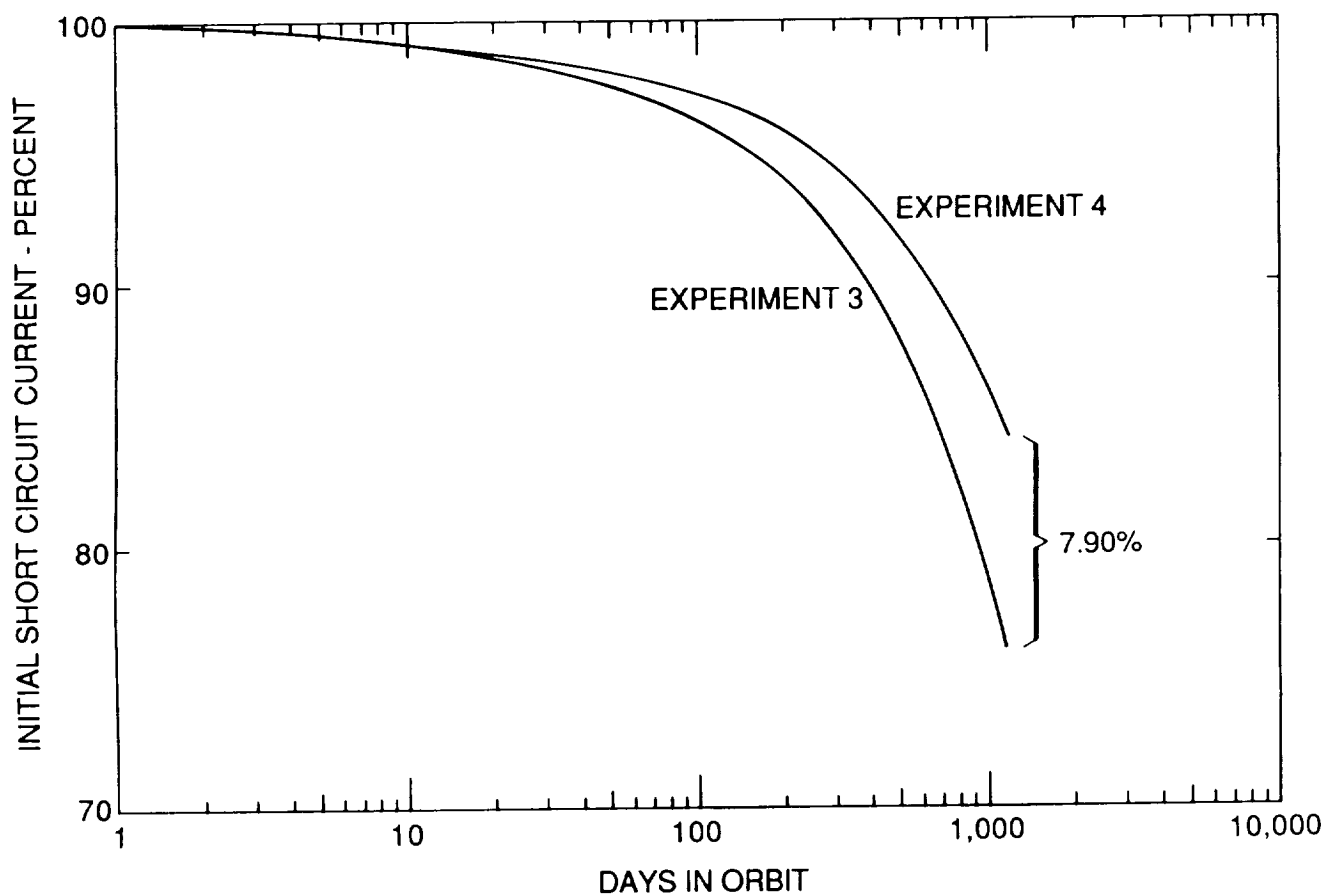


Figure 8

EXPERIMENTS 1 AND 13 SOLAR CELL SHORT CIRCUIT CURRENT DEGRADATION

Similarly, experiments 13 and 1, also contained identical cells. Experiment 1 had its cover slides bonded with organic adhesive R63-489 while experiment 13 had its cover slides electrostatically bonded without any other adhesive. Is it possible that we are throwing away 5% to 10% of available solar power because of degrading adhesive on solar array covers? It is noted that these data (ref 1) contradict data taken on the Applications Technology Satellite (ATS)-6 solar cell experiment in geostationary orbit (ref 2).

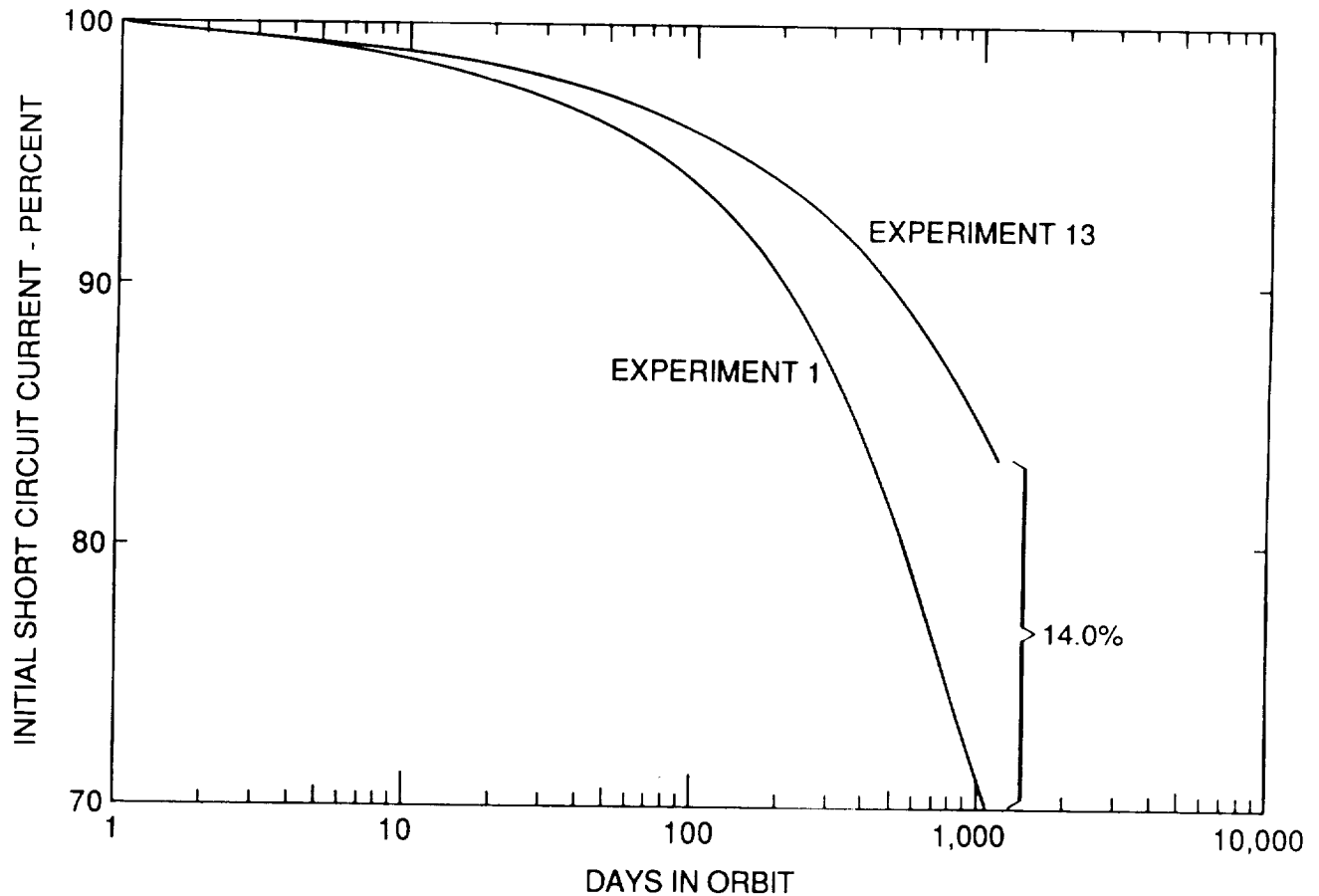


Figure 9

SHUTTLE LAUNCH DISPENSER (SLD) SPACECRAFT SHOWING PROPELLANT TANKS

Although, to our knowledge, NRL has not experienced debris or meteoroid damage, the threat is a design consideration for our space platforms. As an example, when designing the Shuttle Launch Dispenser (SLD), shown in figure 10, the design requirement was that there be greater than 0.99 probability that the propellant tanks would survive the expected meteoroid environment. This was accomplished by performing an analytical study that addressed the problem. First, using perforation equations, the minimum size particle that would penetrate the tank was determined. Then using a flux equation for our orbit, the probability of encountering a particle of this size or larger was determined. Using this approach the tank wall thickness was evaluated. Also, because Multi Layer Insulation thermal blankets were being used, it was decided to use a one-inch standoff for the blankets which produced a "Whipple Meteoroid Bumper" effect and provided additional protection for the tanks. Based on this analysis our tanks have a survival probability of greater than 0.999.

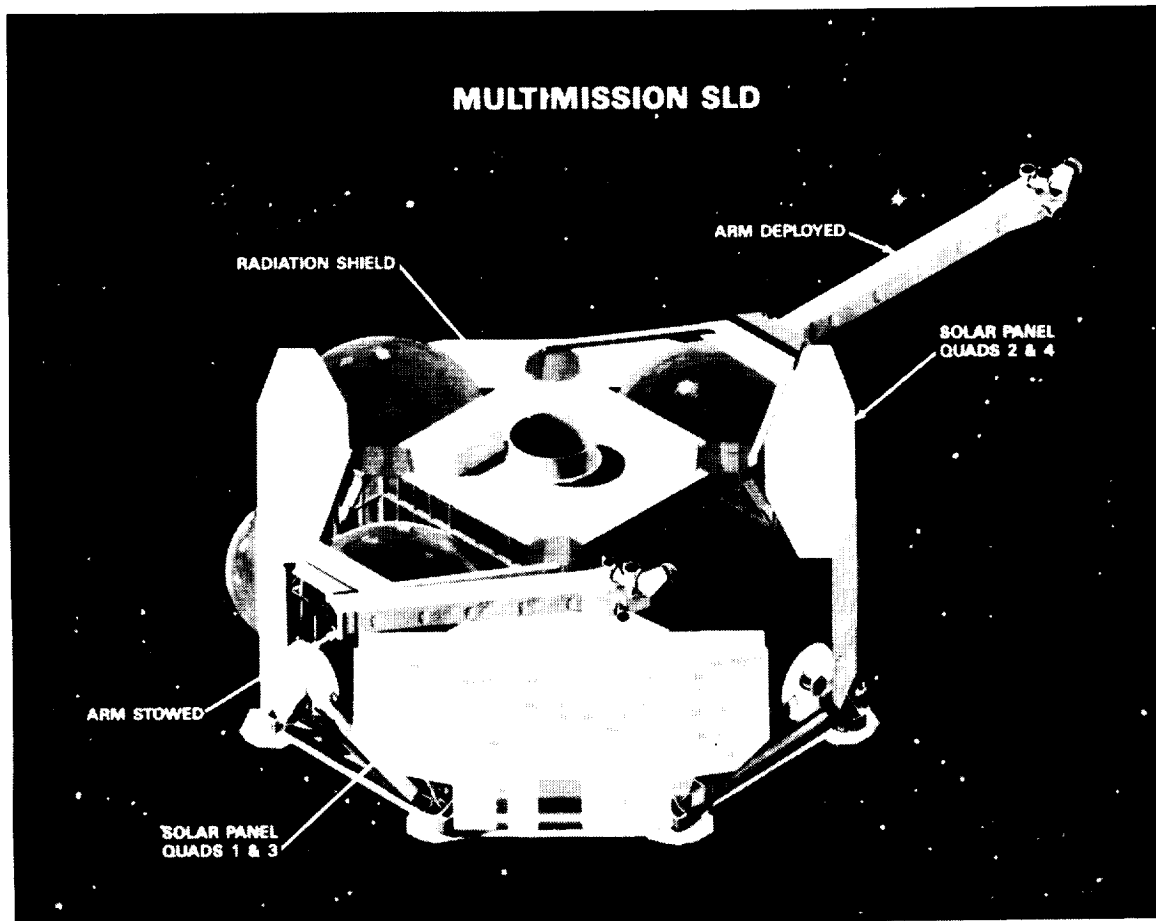


Figure 10

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RELATIVE SOLAR PANEL AND SOLID ROCKET MOTOR POSITIONS

A rough correlation of the contamination of solar panels from solid rocket motor plume has been attempted. A comparison is made from pre-launch solar panel calibration output and post plume exposure data. Data samples are from several satellites. When the data was consolidated and normalized, panel 1, located behind the nozzle, was assigned 100%. Panel 2 averaged 97.0% and panel 3 averaged 97.9% of the panel 1 value.

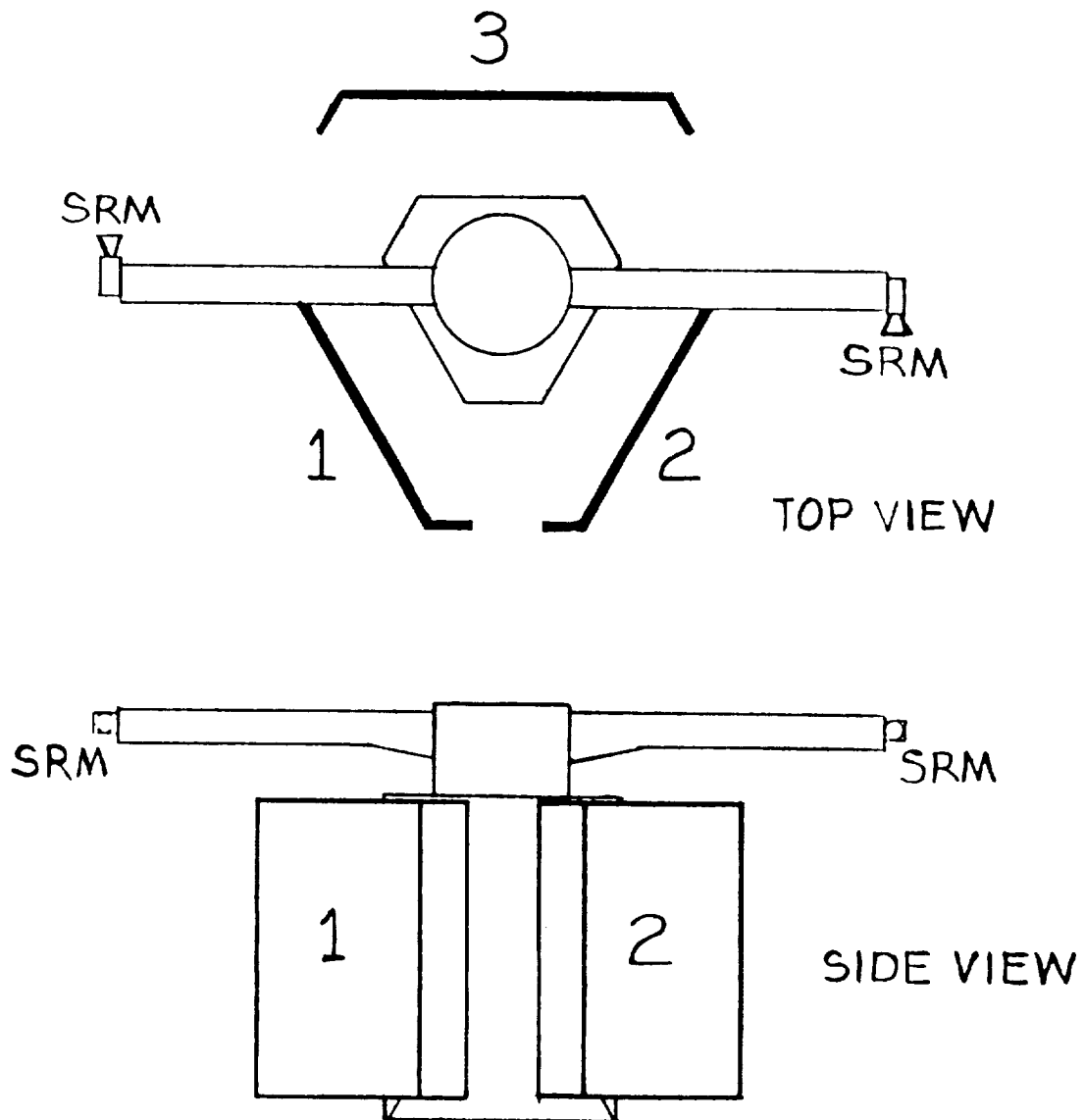


Figure 11

REFERENCES

1. Walker, D.H.; Performance of The Solar Cell Experiments Aboard the NTS-2 Satellite After Three Years in Orbit. NRL Memorandum Report 4580, July 30, 1981.
2. Goldhammer L.J.; ATS-6 Solar Cell Experiment/Improvement. Final Report, NAS Contract NAS 5-22873, 31 January 1977.